Automated Extraction of the Arterial Input Function from Contrast-Enhanced First-Pass Cardiac MR Perfusion Images

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Introduction: Quantitative assessment of myocardial perfusion from first-pass contrast-enhanced cardiac MR (CMR) images has shown clinical value for detecting and diagnosing coronary artery disease [1,2]. Myocardial blood flow and myocardial perfusion reserve can be estimated from the time-signal intensity curves of the left-ventricular (LV) blood cavity and the myocardium. An arterial input function (AIF) which represents arterial contrast enhancement over time is usually obtained by manual tracing of a region of interest (ROI) in the LV cavity over the perfusion image series. This process is time-consuming and can be difficult to exclude papillary muscles from the ROI particularly on systolic phase images. The aim of this study is to develop a fully automated computer method to extract the AIF from the LV cavity of the CMR perfusion images.

Methods: CMR perfusion images of normal volunteers (n=23) and patients with suspected CAD (n=65) were randomly selected to test the performance of the computer method. All subjects underwent both stress and rest perfusion imaging on a 1.5T Siemens scanner. A dual-sequence technique with saturation recovery steady-state free precession sequence was used for all CMR perfusion imaging [3]. For each perfusion study, a low resolution AIF image series was acquired for quantitative perfusion analysis in addition to a high resolution myocardial image series acquired for diagnostic interpretation. This low spatial resolution image series (image matrix 64×48) was specifically designed to maintain the linearity of the LV signal intensity and to avoid AIF distortion. The proposed fully automated method was performed on this low resolution image series to extract the AIF.

The computer method consists of three main steps. First, an algorithm was developed to automatically locate the right-ventricular (RV) and LV blood cavity in the perfusion image series and estimate the timing interval of the contrast enhancement. This algorithm computes radial profiles of the image series to construct a 2D energy matrix. This matrix provides useful spatial and temporal information of the AIF images for detecting the timing interval of the blood cavity contrast enhancement. Next, a differencing image was computed by summing the pixel-wise signal intensity differences before and during the contrast enhancement. This image was used to generate a binary mask covering the LV blood cavity. Last, a signal intensity histogram of the LV pixels in the mask was computed on an image-by-image basis. Pixels with their intensity values greater than a default threshold were used to compute the average intensity value of the blood signal in each image. For validation purposes, a reference standard AIF as defined by manual ROI tracing was compared with the computer automatically extracted AIF.

Results: Figure-1 shows an example of the low resolution perfusion image series as a function of time. The AIF was successfully extracted in all 88 stress and 88 rest perfusion image series by the computer method. The computer AIF has very similar shape and contrast enhancement timing interval with the manual AIF on the vast majority of the perfusion series (figure-2). In 9 of the total 176 image series, there were minor deviations of the LV contrast enhancement timing. Further investigation indicates that this was due to an imperfect LV image masking that included small regions of the RV blood cavity.

For quantitative comparison of the computer vs. manual AIF curves, Pearson correlation coefficient averaged 0.995±0.008 for the entire dataset. There were only 14 of the 176 image series that had a correlation coefficient less than 0.990 (minimum R=0.932). The average signal intensity difference between computer and manual AIF was 3.5±2.1% of the peak signal intensity. There were more cases with positive than negative differences at the peak signal intensity of the AIF (166 vs. 10). This may have been due to better segmentation of the papillary muscles from the blood cavity by the computer AIF extraction.

Discussion: We presented an automated computer method to extract the AIF from contrast-enhanced first-pass CMR perfusion images. This method was tested in 176 perfusion image series and the results matched closely with a reference AIF defined by the manual tracing. This computer method can reduce the processing time needed to obtain AIF for estimating quantitative perfusion. It may also reduce imperfections in the manual tracing of the blood cavity by excluding the papillary muscles, and thus obtain better dynamic range of the AIF during arterial contrast enhancement.

Reference:

1. Utz, et al., MRM, 2008, 1373-1377
2. Groothuis, et al., JMRI, 2010, 88-93
3. Gatehouse et al., JMRI, 2004, 39-45

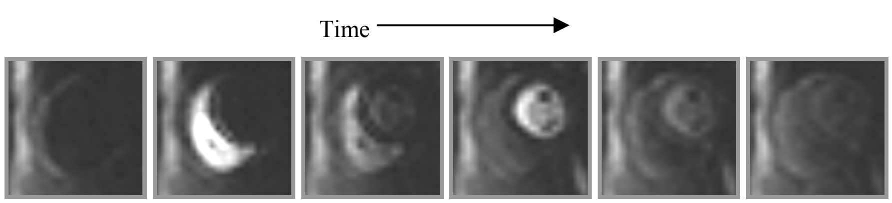

Figure-1

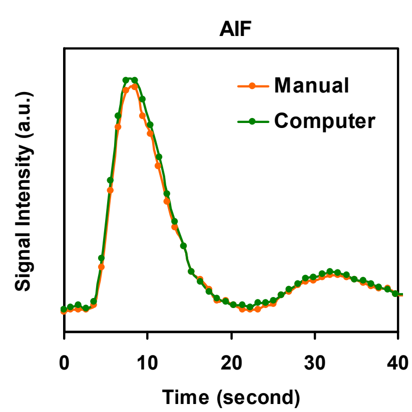

Figure-2